drought tips

Number 92-45

Central Coast Crop Coefficients for Field and Vegetable Crops

Knowing how much irrigation water to apply to a crop is particularly important during a drought, and knowing the rate at which water is lost from the plant as it grows (*crop evapotranspiration*) is helpful in determining how much water to apply. The water loss rate is affected by the *crop coefficient*—such factors as how irrigation is managed and the way a particular crop develops in different geographic areas.

This leaflet gives crop coefficients for Central Coast field and vegetable crops and describes how to determine crop evapotranspiration.

Crop Evapotranspiration

Water is lost from a field as it evaporates from soil and plant surfaces (evaporation) and from inside plant leaves (transpiration). Together, evaporation (E) and transpiration (T) are called evapotranspiration (ET). In cultivated crops, ET is called crop evapotranspiration (ETc). Daily ETc is called the ETc rate, and cumulative ETc (CETc) is the sum of daily ETc values over a given number of days. The ETc rate depends on the drying power of the air (evaporative demand), and it increases and decreases with changes in solar radiation and other weather factors.

ETc can be found by multiplying reference evapotranspiration (ETo) by a crop coefficient (Kc):

$$ETc = ETo \times Kc \qquad \textbf{(1)}$$

where ETo is the estimated evapotranspiration of a 4- to 6-inch tall cool-season grass and Kc is a crop coefficient that converts ETo to ETc. ETo is mainly influenced by changes in solar radiation, but it also responds to changes in temperature, humidity, and wind speed. In well-managed irrigated crops, differences in soil type have little effect on ETc, but they do influence the timing of irrigations (see ***drought tips*** 92-62).

Reference evapotranspiration

Reference evapotranspiration is the factor that adjusts ETc for changing evaporative demand (weather). Using current ETo to estimate ETc helps growers maintain high production and use water efficiently. See ***drought tips*** 92-20 for further information on scheduling irrigations using current ETo data.

Current ETo data are available from the California Irrigation Management Information System (CIMIS) through a direct computer dial-up service. Current ETo information is also available through local water districts and news media in some areas and through the ATI-NET computer network. ETo forecasts are disseminated by the National Weather Service in some regions of California. For information on locating or accessing CIMIS information, write to:

The California Department of Water Resources
Water Conservation Office
P.O. Box 942836
Sacramento, CA 94236-0001

Crop Coefficients

Crop coefficients are determined by experimentally comparing measured ETc and measured or estimated ETo according to the ratio in Equation 2.

$$Kc = ETc + ETo \qquad \textbf{(2)}$$

The Kc corresponds to a particular crop, growth stage, and set of management practices. In future seasons, when the crop reaches the same growth stage, through the same irrigation management practices, the appropriate Kc is multiplied by ETo to estimate ETc.

Crop coefficients are affected by irrigation management practices and change as the crop grows and ages. Soil surface wetting has a significant influence on the ETc rate—frequent wetting by rainfall or irrigation increases ETc relative to ETo and results in a higher Kc. Since most of the soil surface is exposed to sunlight from planting until approximately 10 percent shading by the crop foliage, a higher Kc is needed for fields that are frequently wetted by rainfall or irrigation during early growth. Drip-irrigated field crops have lower Kc values during early growth because the soil surface between rows remains drier.

As a crop canopy develops (during the rapid growth period), transpiration becomes the dominant component of ETc and soil surface wetness has less influence on ET rates. During midseason and late season, ETc is mostly transpiration, and the ETc rate of most agronomic and

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vegetable crops is near or slightly greater than the ETo rate.

Late in the season, the ETc rate of many agronomic crops declines relative to ETo because of aging, so the Kc decreases. Most vegetable crops are harvested before aging affects ETc and therefore there is no late period decrease in Kc. Figure 1 shows the general shape of a crop coefficient curve for agronomic crops, and Figure 2 shows the shape of a Kc curve for vegetable crops and strawberries.

Agronomic Crops

Specific growth and development dates (dates A-E) separate the growth periods shown in Figures 1 and 2. For agronomic crops, the dates correspond to planting (date A), 10% ground shading (date B), 75% or peak ground shading (date C), beginning of senescence (date D), and harvest (date E). The Kc for initial growth (dates A to B) is a constant selected from Table 2; the Kc value for midseason (dates C to D) is a constant selected from Table 3; and the Kc at the end of the season (date E) is selected from Table 3. The Kc values during rapid growth increase linearly from the Kc on date B to that on date C. Similarly, the Kc values during late season decrease linearly from the Kc on date D to date E.

Midseason and end-of-season Kc values recommended for agronomic crops are given in Table 3, along with the approximate number of days making up each growth period. Growth period lengths vary depending on crop variety and weather in any given season. Since crops develop faster when temperatures are warmer than normal, growth periods are shortened during warm seasons and lengthened when seasons are cooler than normal. Growers should therefore adjust growth periods according to the conditions at hand.

Vegetable Crops

Vegetable crop Kc values during initial and rapid growth periods are determined the same way they are for agronomic crops, but most vegetable crops have a constant Kc value near 1.0 from 75% or peak ground shading until the end of the season (the crops are harvested before the Kc declines). Vegetable crops may differ slightly in this peak Kc value, but Kc = 1.0 can be used with little loss in accuracy. The length of initial and rapid growth periods differs considerably among crops and varieties. The number of days from planting to 10% ground shading and from 10% ground shading to 75% or peak ground shading must be estimated from experience. If the crop is transplanted rather than seeded, the initial growth period may be very short.

Strawberries

Little research has been conducted on the Kc value for strawberries, but one study reported that a constant Kc = 0.7 resulted in good production near Watsonville [McNiesh 1985]. This Kc value is likely to give similar results in other strawberry-producing areas of California. During initial and rapid growth periods, the Kc can be determined using the same procedure as that used to determine the Kc for agronomic and vegetable crops Growers should use a constant Kc = 0.7 from 75% or peak ground shading until the end of the season.

Initial Growth Period Kc Values

Although Kc values change during a cropping season, the Kc values of sprinkler-irrigated or surface- irrigated crops or of crops that receive rainfall during initial growth depend on the average irrigation and rainfall frequency and the average ETo rate during the initial growth period. Table 1 provides estimated Kc values growers can use for a range of average ETo rates and irrigation and/or rainfall frequency. The ETo rate and irrigation and/or rainfall frequency are estimated based on historical average records and experience. Historical average ETo rates are given in Table 2.

On the coast, ETo rates may be 25% to 33% less than indicated for coastal valleys and plains in Table 2. In those areas, ETc should be reduced appropriately. ETc rates may be slightly higher than listed in Table 2 in the upper Salinas Valley when the field is surrounded by unirrigated natural vegetation or bare soil.

Using drip irrigation rather than sprinkler or surface irrigation reduces the Kc during the initial growth period, but all irrigation methods have similar Kc values after date C. Little research has been conducted to determine Kc values of drip-irrigated field, vegetable, and strawberry crops, but using Table 1 and a frequency of 20 days should provide a reasonably good Kc estimate for the initial growth period. For example, if the average daily ETo rate is 0.20 inches per day, a Kc = 0.22 corresponding to a 20-day irrigation and rainfall frequency is selected from Table 1 for use from planting until the crop attains approximately 10% ground shading.

Using ETo for Scheduling Irrigations

Current ETo data from CIMIS can be used to adjust ETc estimates for the current weather. Using Equation 1, multiply the CIMIS ETo rate by the corresponding Kc from your Kc curve to obtain an estimated current ETc rate. The daily ETc rates are added to calculate cumulative ETc over a time interval. Assuming there is no rainfall, fog, or water table contribution to the crop's water use, cumulative ETc provides an estimate of the soil water depletion.

Irrigation timing is based on the management allowable depletion (MAD). This is the maximum amount of water that can be

Table 1. Average crop coefficient (Kc) values during initial growth of young (≤ 10% cover), sprinkler irrigated crops for a range of average ETo rates and irrigation and/or rainfall frequency.

ETo	Average irrigation and rainfall frequency—days									
in./day	2	4	6	8	10	12	14	16	18	20
0.05	1.05	0.92	0.78	0.70	0.62	0.59	0.55	0.50	0.46	0.43
0.10	0.98	0.82	0.69	0.59	0.52	0.50	0.46	0.42	0.38	0.35
0.15	0.93	0.74	0.58	0.50	0.43	0.40	0.37	0.34	0.31	0.28
0.20	0.88	0.66	0.50	0.42	0.37	0.33	0.30	0.28	0.25	0.22
0.25	0.85	0.60	0.45	0.38	0.34	0.30	0.28	0.25	0.21	0.19
0.30	0.81	0.57	0.41	0.35	0.30	0.28	0.25	0.23	0.19	0.18
0.35	0.79	0.54	0.39	0.32	0.28	0.25	0.23	0.21	0.18	0.17

depleted from the soil between irrigations without loss in crop production or that fits within the schedule of other on-farm management factors. See ***drought tips*** 92-62 for information on selecting a management allowable depletion.

The amount of irrigation water to apply is determined by dividing the soil water depletion below field capacity by the application efficiency of the irrigation system. For drip- and sprinkler-irrigated crops without surface runoff, the distribution uniformity of the system provides a good estimate of the application efficiency if the amount applied is calculated as the soil water depletion divided by the distribution uniformity. For example, if the distribution uniformity of the system is 80% and the soil water depletion is 1 inch, the amount to apply equals 1.25 inches (= 1 inch + 0.8). Although only 1 inch of water was depleted from the soil, 1.25 inches must be applied to ensure that most of the field receive 1 inch or more. Local farm advisors or USDA-SCS Offices can provide information on how to determine distribution uniformity. See ***drought tips*** 92-23 for information on determining efficiency of furrow irrigation.

References

Doorenbos, J. and W.O. Pruitt. 1977. *Crop water requirements*. FAO Irrigation and Drainage Paper 24. United Nations Food and Agriculture Organization, Rome.

Goldhamer, D.A. and R.L. Snyder (Eds.). 1989. *Irrigation scheduling: A guide for efficient on-farm water management*. University of California Publication 21454. Oakland, CA.

McNiesh, C.M. 1985. *Pajaro valley irrigation project. Final Report to the Association of Monterey Bay Area Governments*.

Hanson, B.R. 1992. *Furrow irrigation*. University of California *drought tips* 92-23.

Snyder, R.L. 1992. *Irrigating up crops efficiently with sprinklers*. University of California *drought tips* 92-52.

Snyder, R.L., S.R. Grattan, and H.L. Sheradin. 1992. *Selecting a management allowable depletion (MAD)*. University of California *drought tips* 92-62.

Table 2. Daily and cumulative reference evapotranspiration (ETo) data every 10th day of the year for Central Coast Interior Valleys and Coastal Valleys and Plains.

Date	Coastal Valleys and Plains		Interior Valleys	
	in./day	in.	in./day	in.
Jan 10	0.05	0.48	0.05	0.46
Jan 20	0.06	1.07	0.05	0.98
Jan 30	0.07	1.71	0.06	1.57
Feb 9	0.07	2.41	0.07	2.23
Feb 19	0.08	3.16	0.08	2.99
Mar 1	0.09	3.99	0.09	3.85
Mar 11	0.10	4.91	0.10	4.82
Mar 21	0.11	5.92	0.11	5.90
Mar 31	0.12	7.05	0.13	7.09
Apr 10	0.13	8.26	0.14	8.41
Apr 20	0.13	9.57	0.15	9.85
Apr 30	0.14	10.95	0.17	11.44
May 10	0.15	12.41	0.18	13.16
May 20	0.15	13.93	0.19	15.01
May 30	0.16	15.49	0.20	16.94
Jun 9	0.16	17.09	0.20	18.95
Jun 19	0.17	18.72	0.21	21.02
Jun 29	0.17	20.40	0.21	23.14
Jul 9	0.17	22.10	0.22	25.30
Jul 19	0.17	23.81	0.21	27.46
Jul 29	0.17	25.49	0.21	29.56
Aug 8	0.16	27.10	0.20	31.59
Aug 18	0.15	28.64	0.19	33.52
Aug 28	0.14	30.10	0.18	35.35
Sep 7	0.13	31.47	0.17	37.08
Sep 17	0.13	32.76	0.16	38.71
Sep 27	0.12	33.97	0.15	40.22
Oct 7	0.11	35.10	0.13	41.61
Oct 17	0.10	36.16	0.12	42.87
Oct 27	0.09	37.12	0.10	43.98
Nov 6	0.08	37.98	0.09	44.93
Nov 16	0.07	38.74	0.08	45.74
Nov 26	0.06	39.41	0.06	46.43
Dec 6	0.05	39.99	0.05	47.02
Dec 16	0.05	40.49	0.05	47.53
Dec 26	0.04	40.95	0.04	47.99

Table 3. Crop coefficient (Kc) values Kc2 for midseason and Kc3 for the end-of-season and growth period length in days for agronomic crops.

Crop	Kc2	Kc3	Initial	Rapid	Mid-season	Late-season
Beans (dry)	1.05	0.30	20	35	70	40
Cereals*	1.05	0.25	20	25	60	30
Sugarbeet	1.05	0.75	45	75	80	30

***Cereals include: wheat, barley, and oats. Data in this table were estimated from Tables 21 and 22 in Doorenbos and Pruitt [1977]. The Kc for intial growth is selected from Table 1.**

Figure 1. Generalized crop coefficient curve for fleld crops

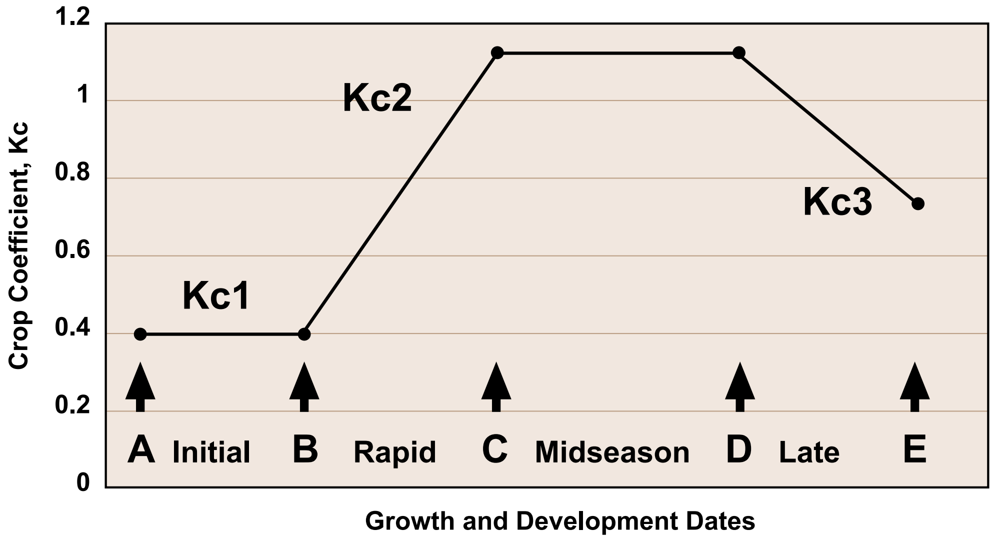
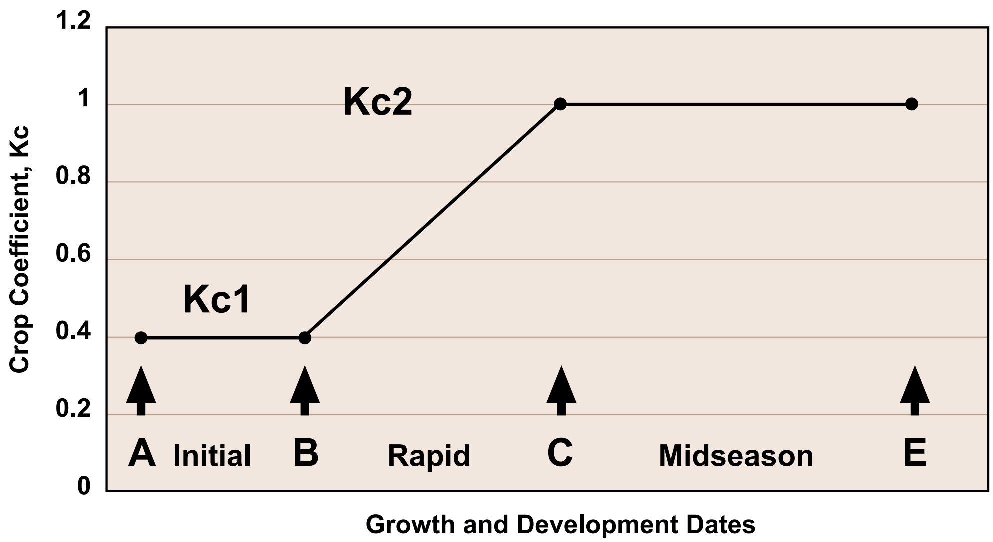


Figure 2. Generalized crop coefficient curve for vegetable crops.



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